UiT The Arctic University of Norway

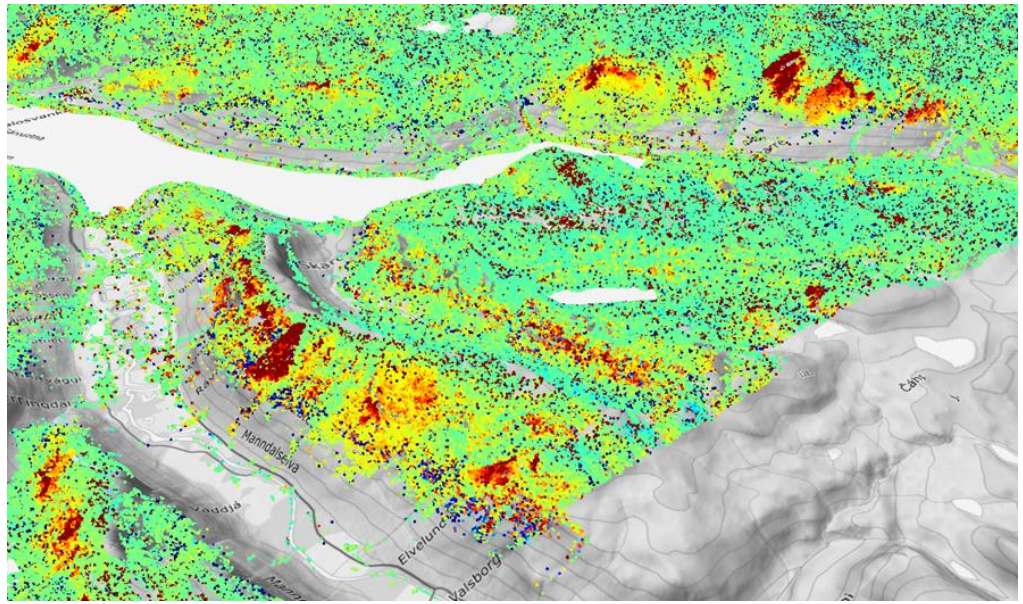
Large mountain rockslides in Norway and their controls

Louise Vick

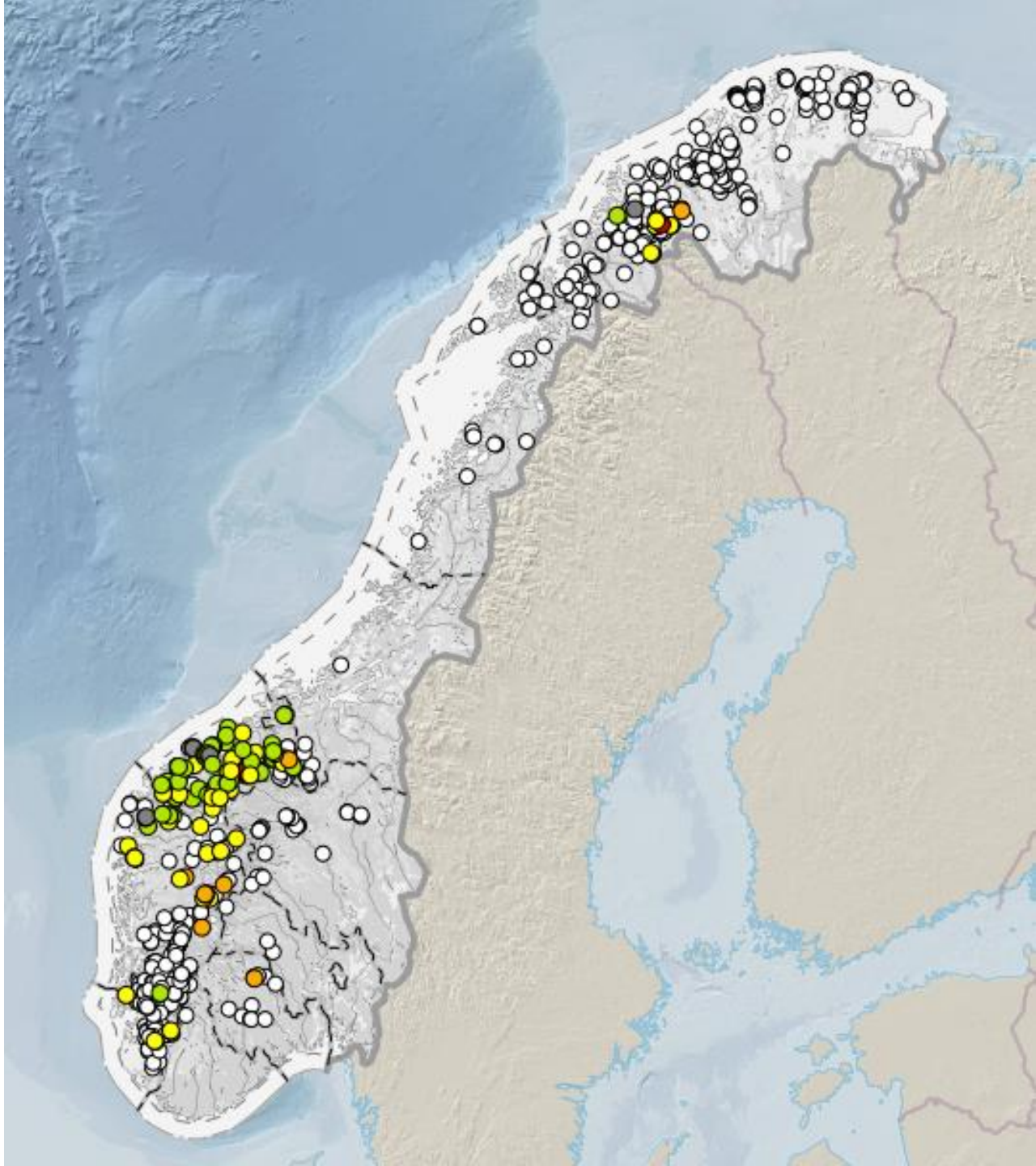
Contents

- Introduction to problem type
- Environmental controls and geological history
- Case study 1: Jettan
- Case study 2: Dusnjarga
- Hazard and risk management

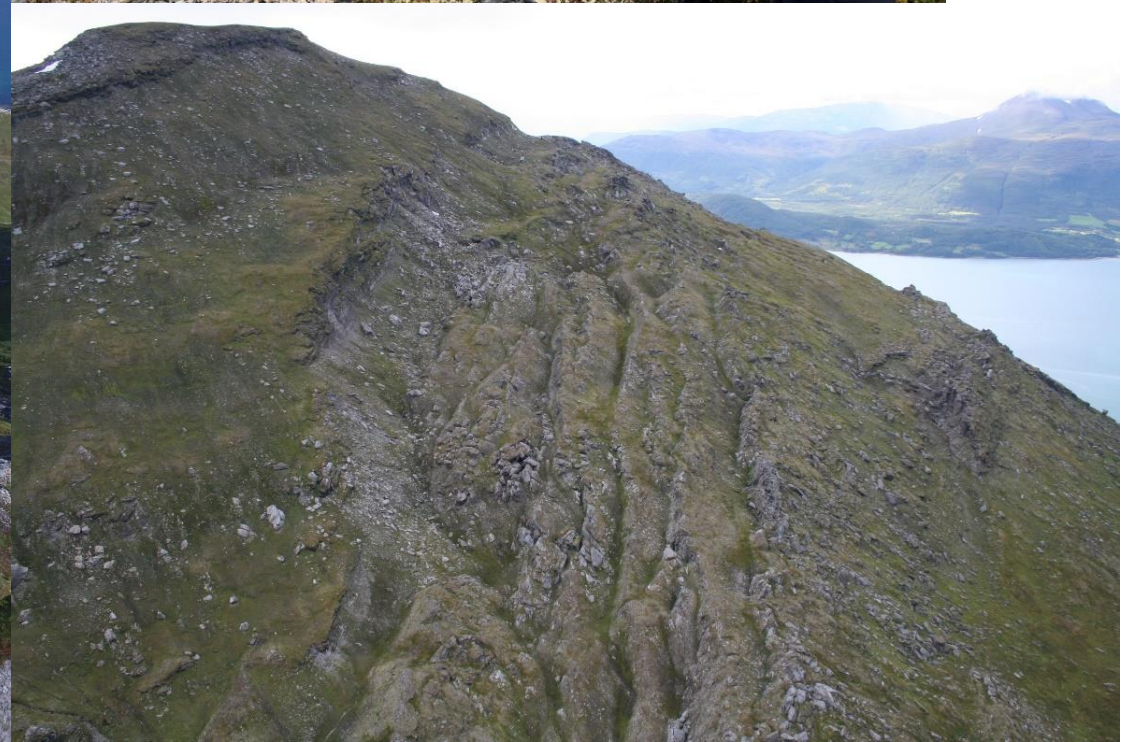
- 673 objects (113 mapped)
- 10 continually monitored
- 13 periodically monitored



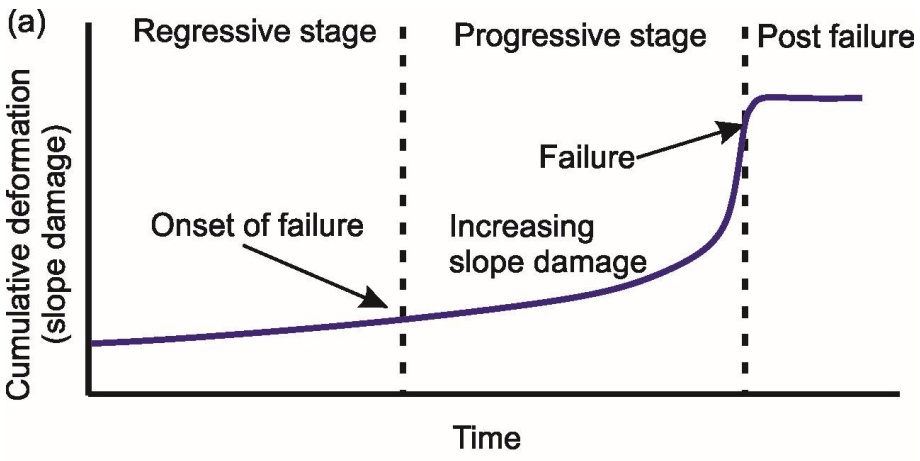
www.insar.ngu.no

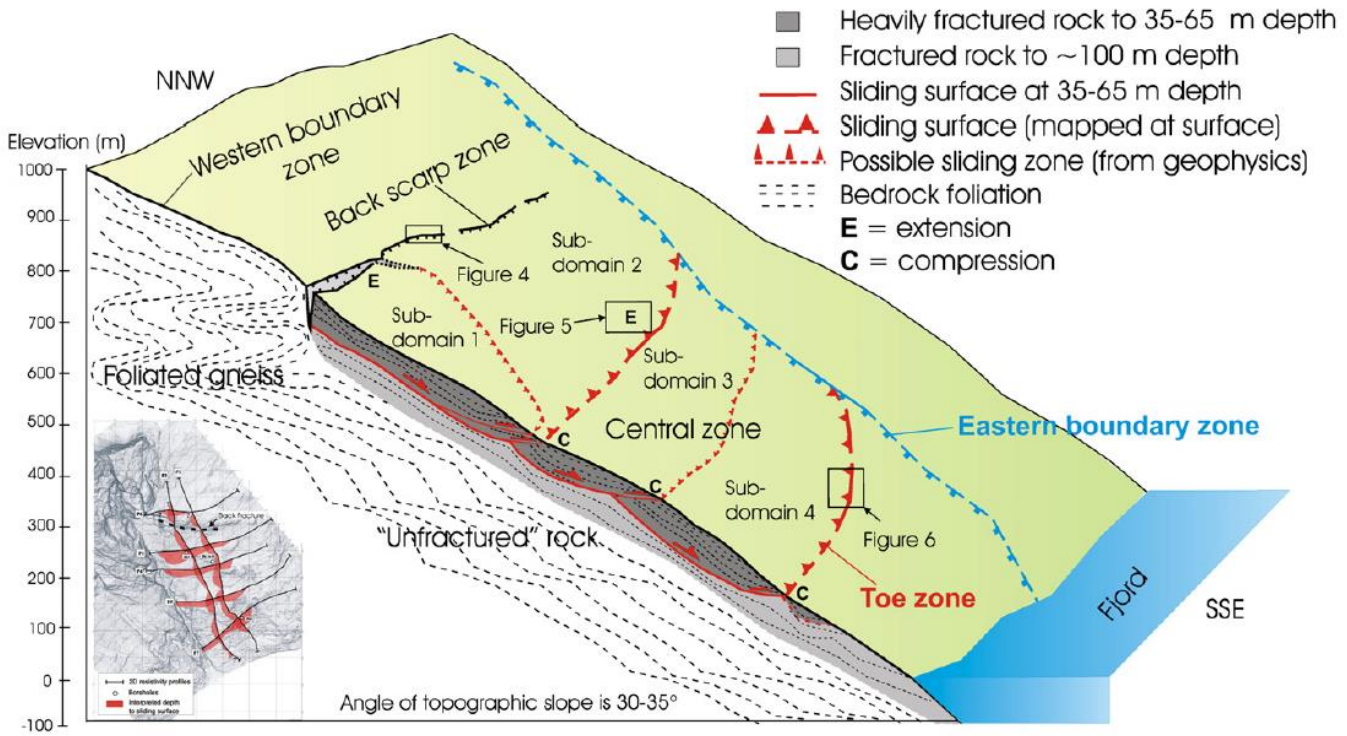


- Rock slopes
- Creeping movements (mm a-1)
- Large scale: ridge crest to toe
- Slope deformation as morphostructure



Mechanism

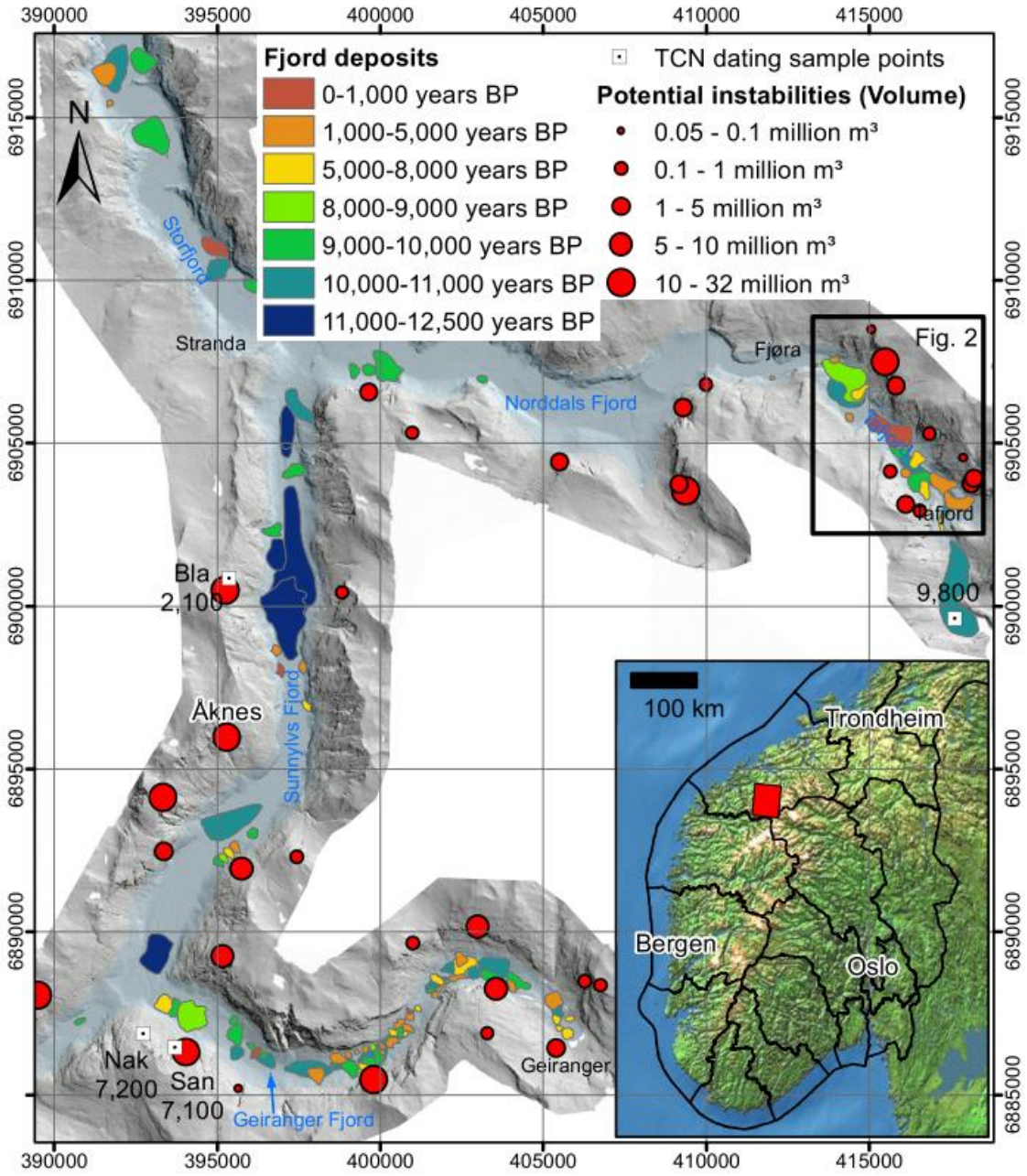




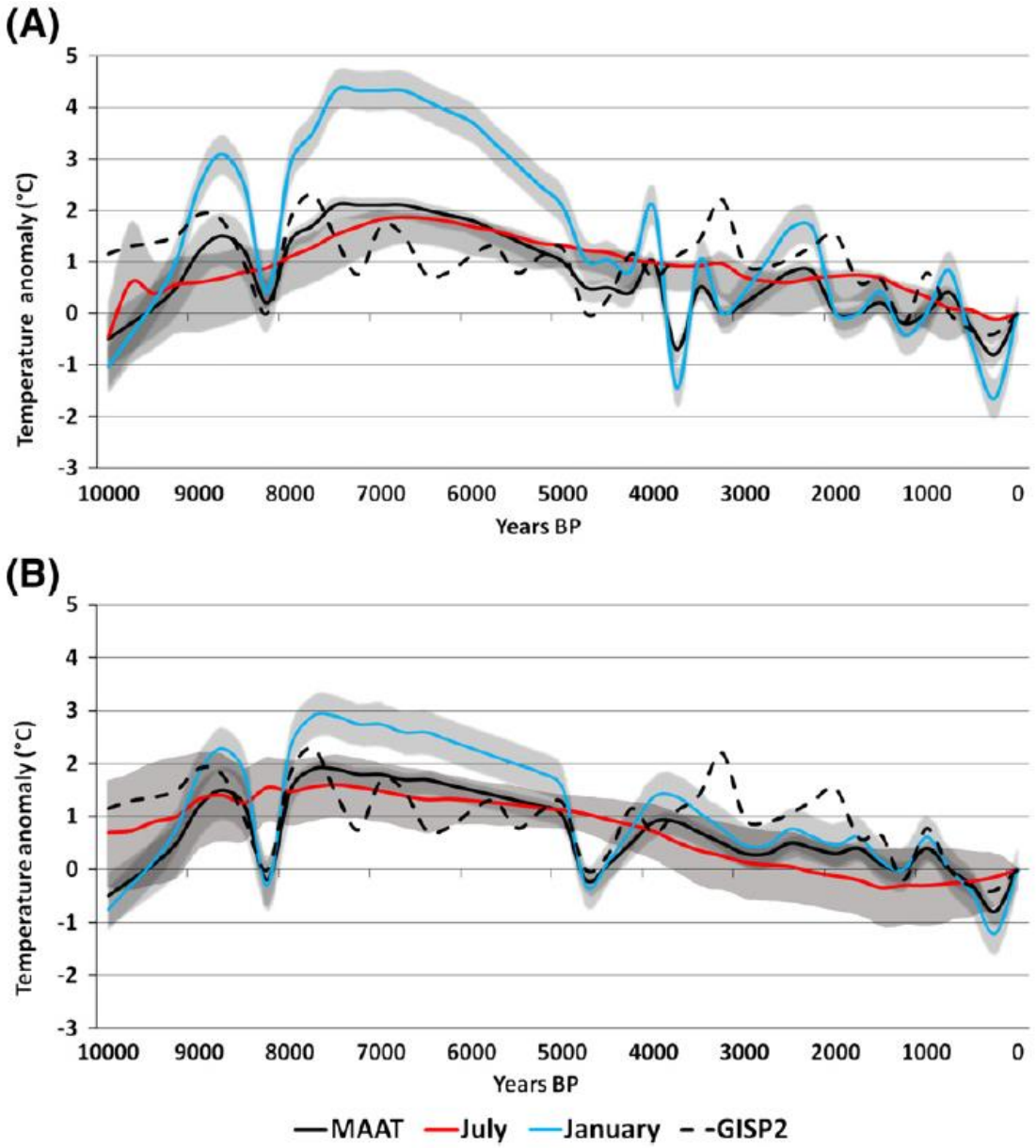
Ganerød et al 2008

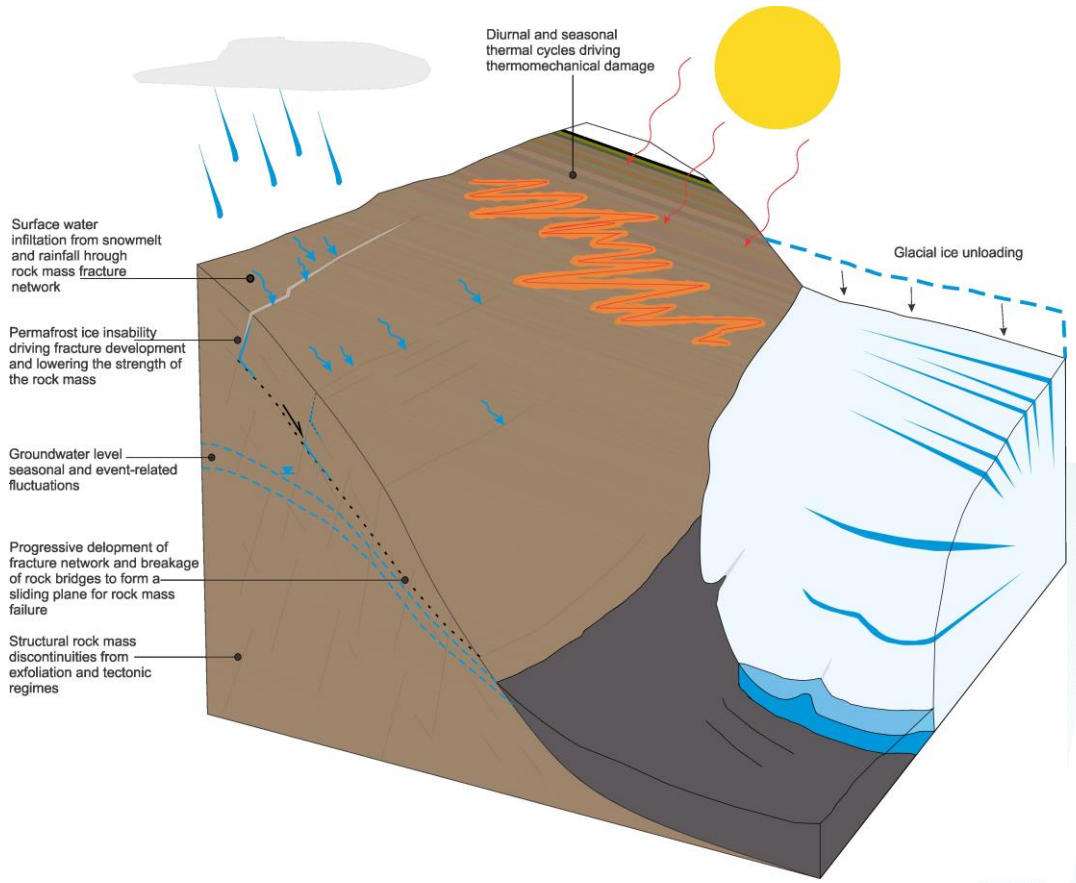
Gamanjunni-3

Nomedalstinden

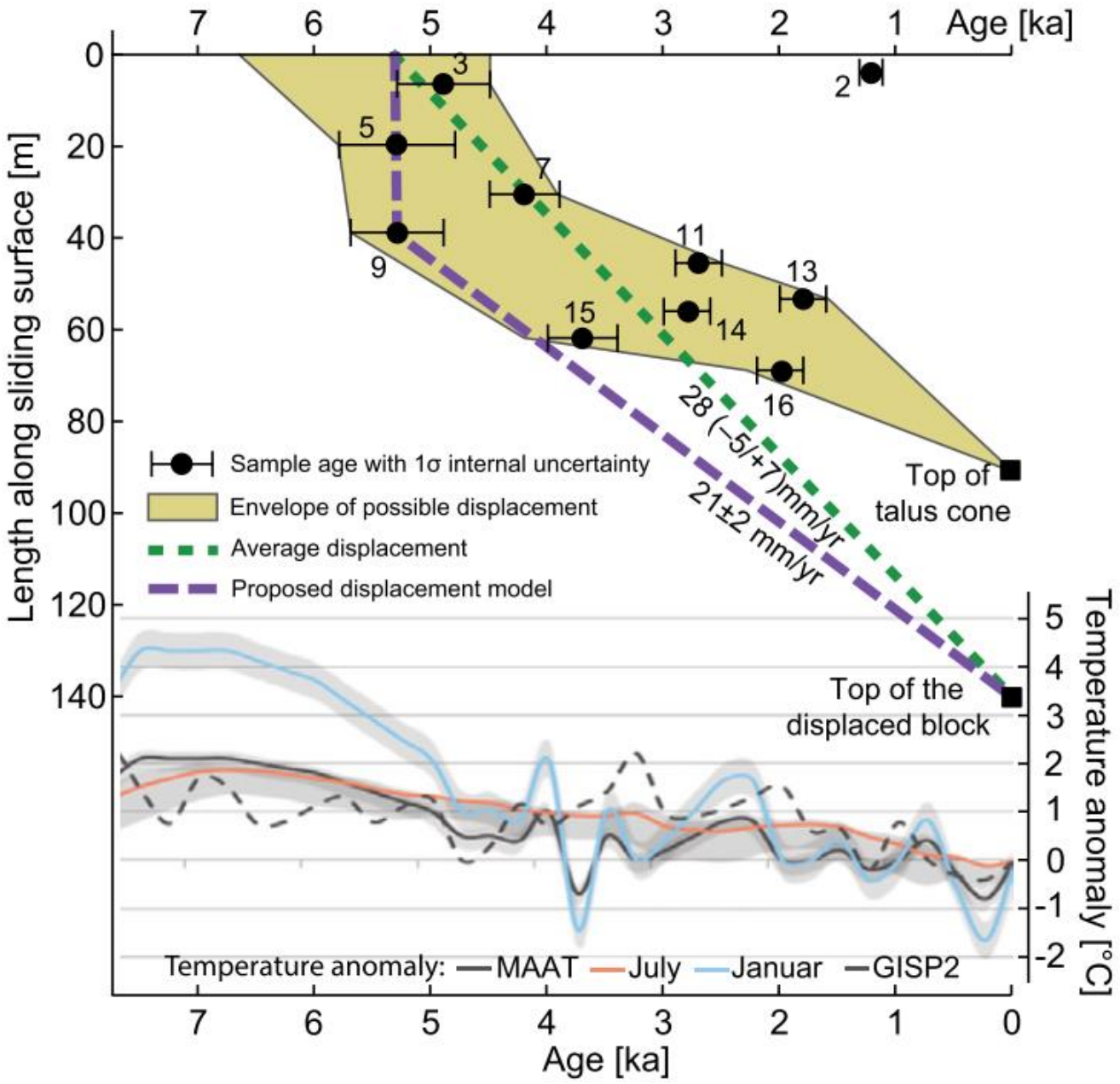


Böhme et al., 2015

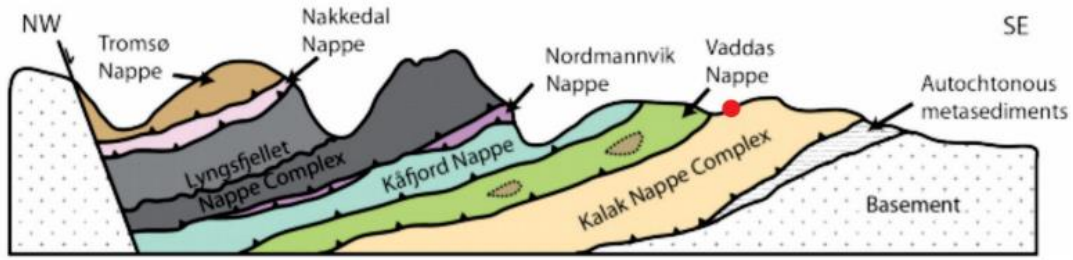



Diurnal and seasonal thermal cycles driving thermomechanical damage
Surface water infiltation from snowmelt and rainfall hrough rock mass fracture network
Permafrost ice insability driving fracture development and lowering the strength of the rock mass
Groundwater level seasonal and event-related fluctuations
Progressive delopment of fracture network and breakage of rock bridges to form a sliding plane for rock mass failure
Structural rock mass discontinuities from exfoliation and tectonic regimes
Glacial ice unloading

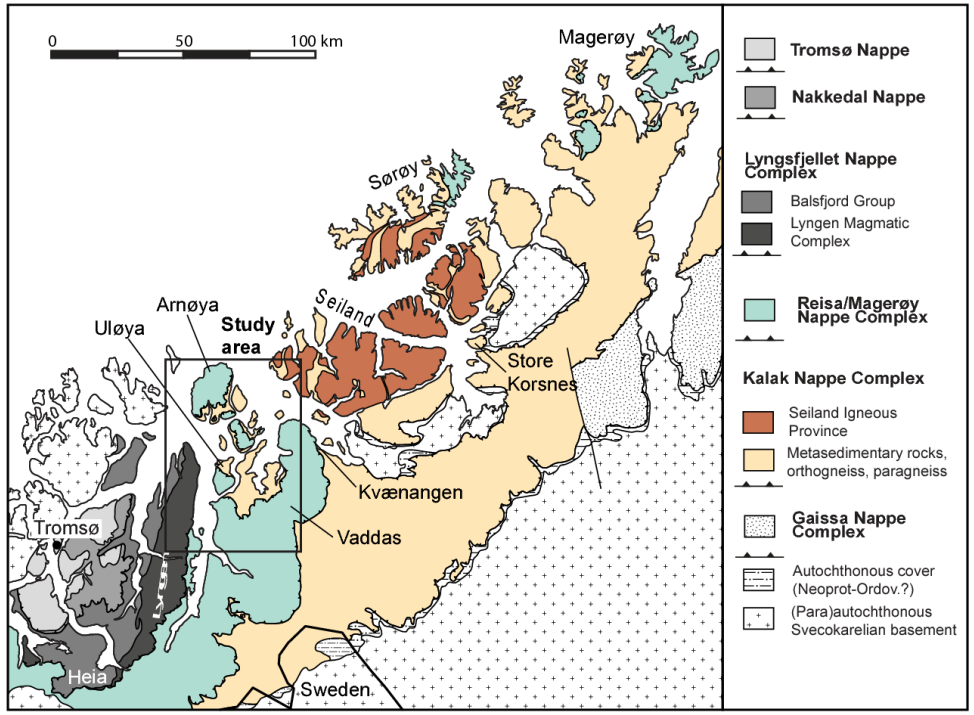
Lilleøren et al 2012



Böhme et al., 2019



Faber, 2018



- Formation of mountains
- Caledonian orogeny
- Dominant dip of foliation and thrusts to NW

- Rift margin opening
- Dominant fault directions NW, NE, NNW
- Dominant joint directions follow
- Joints steeply dipping

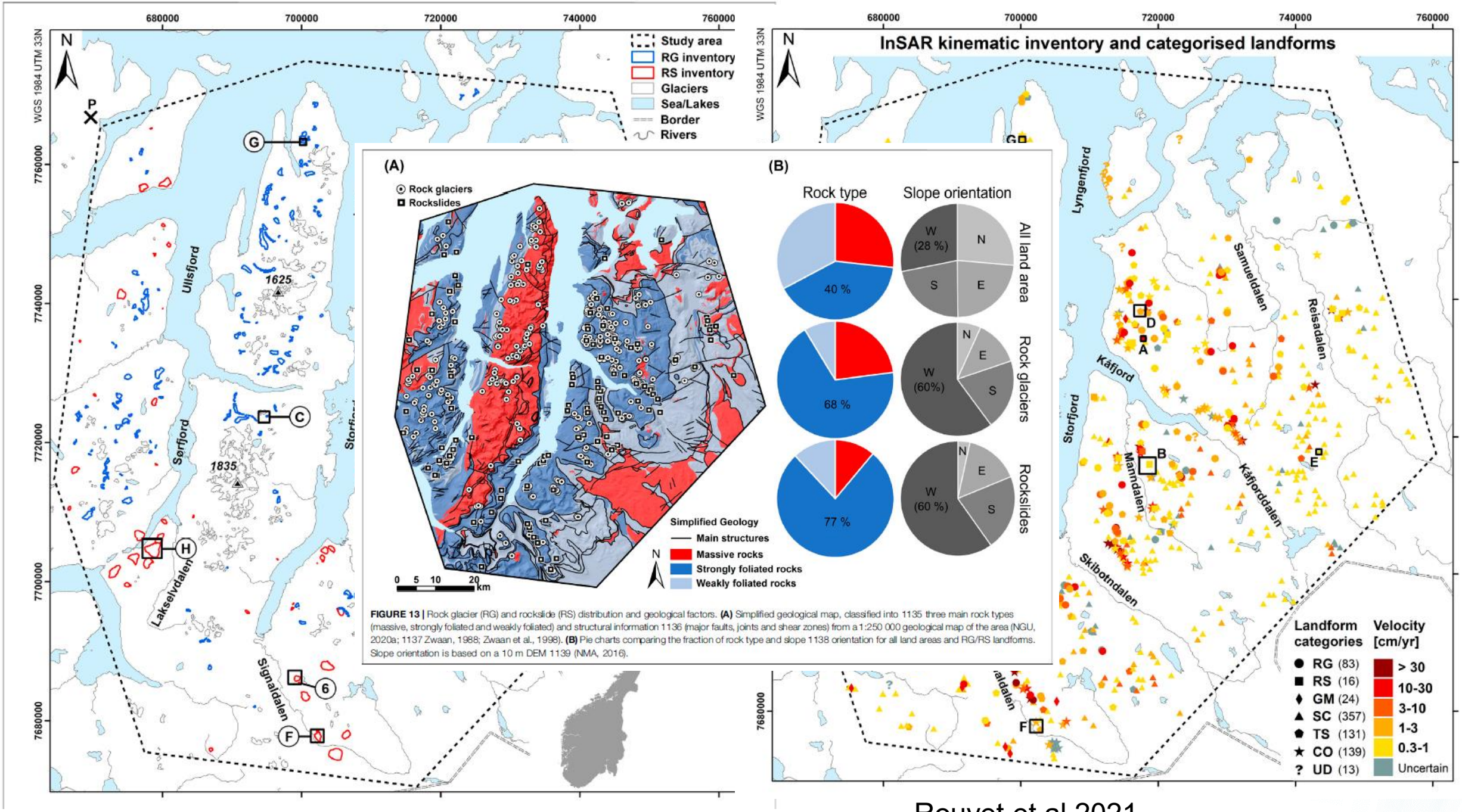


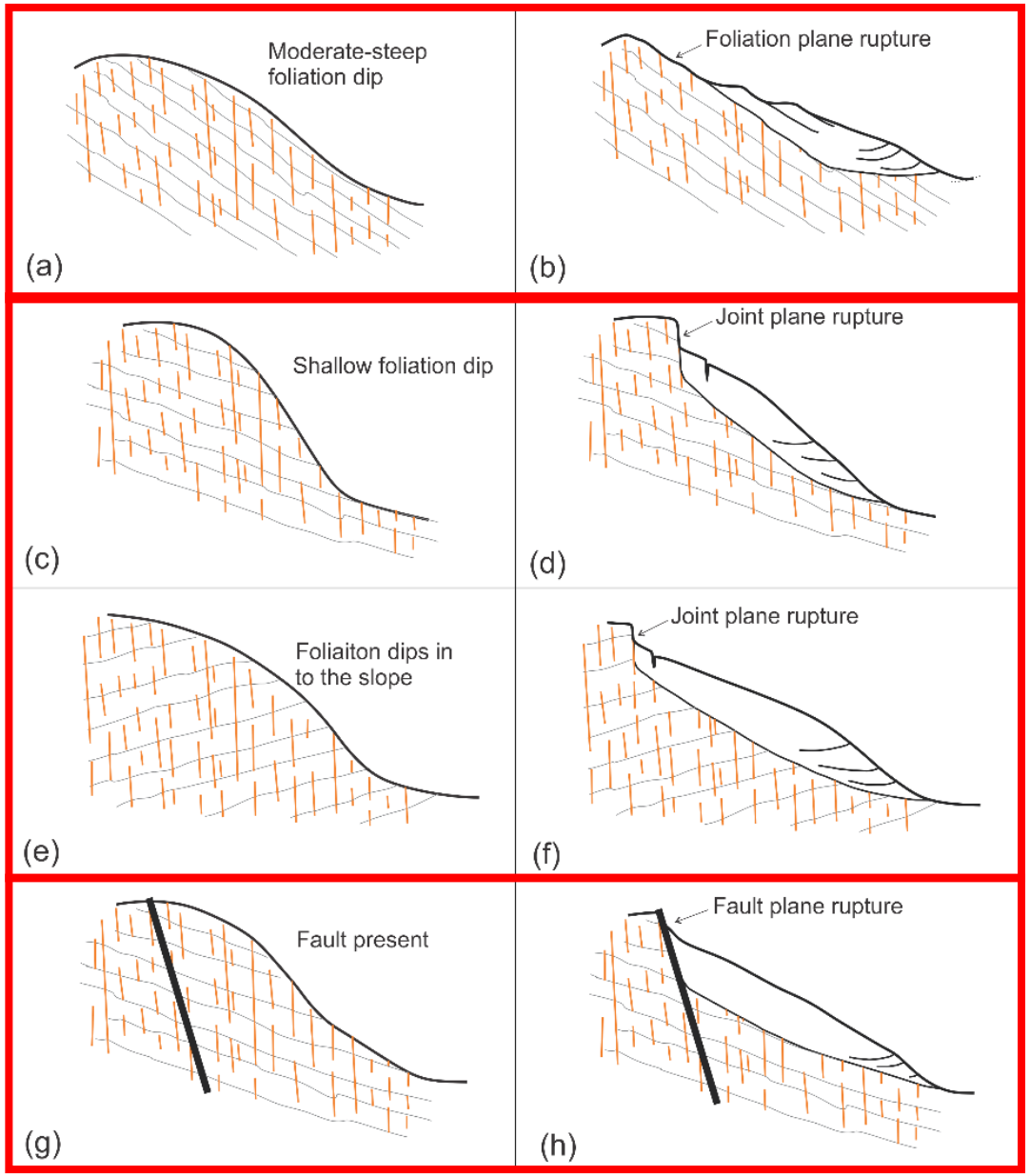
FIGURE 13 | Rock glacier (RG) and rockslide (RS) distribution and geological factors. **(A)** Simplified geological map, classified into 1135 three main rock types (massive, strongly foliated and weakly foliated) and structural information 1136 (major faults, joints and shear zones) from a 1:250 000 geological map of the area (NGU, 2020a; 1137 Zwaan, 1988; Zwaan et al., 1998). **(B)** Pie charts comparing the fraction of rock type and slope 1138 orientation for all land areas and RG/RS landforms. Slope orientation is based on a 10 m DEM 1139 (NMA, 2016).

Rouyet et al 2021

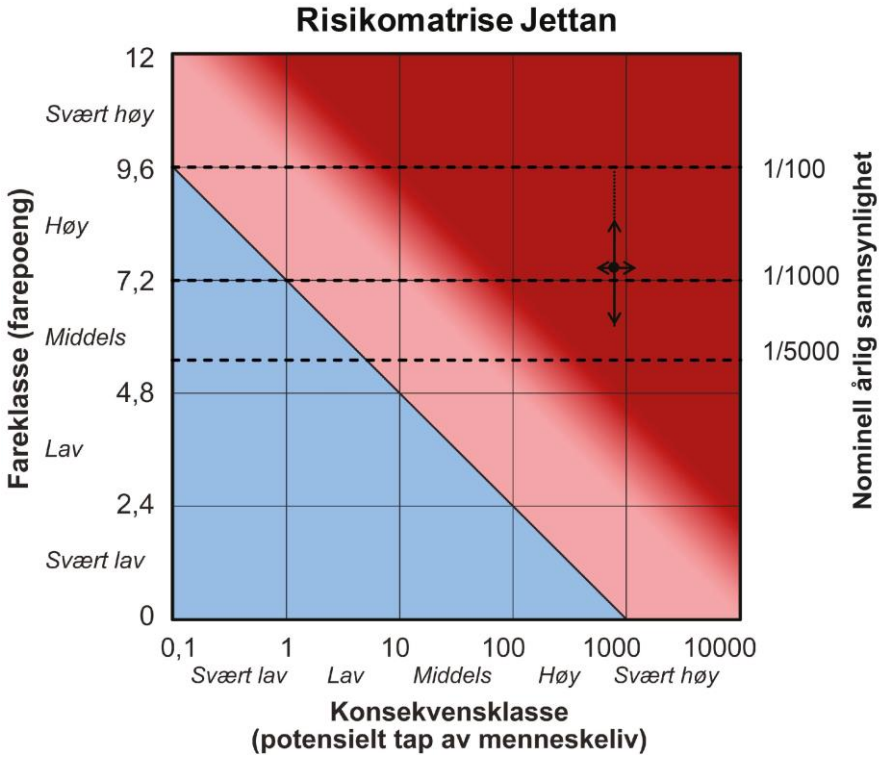
Foliation-controlled

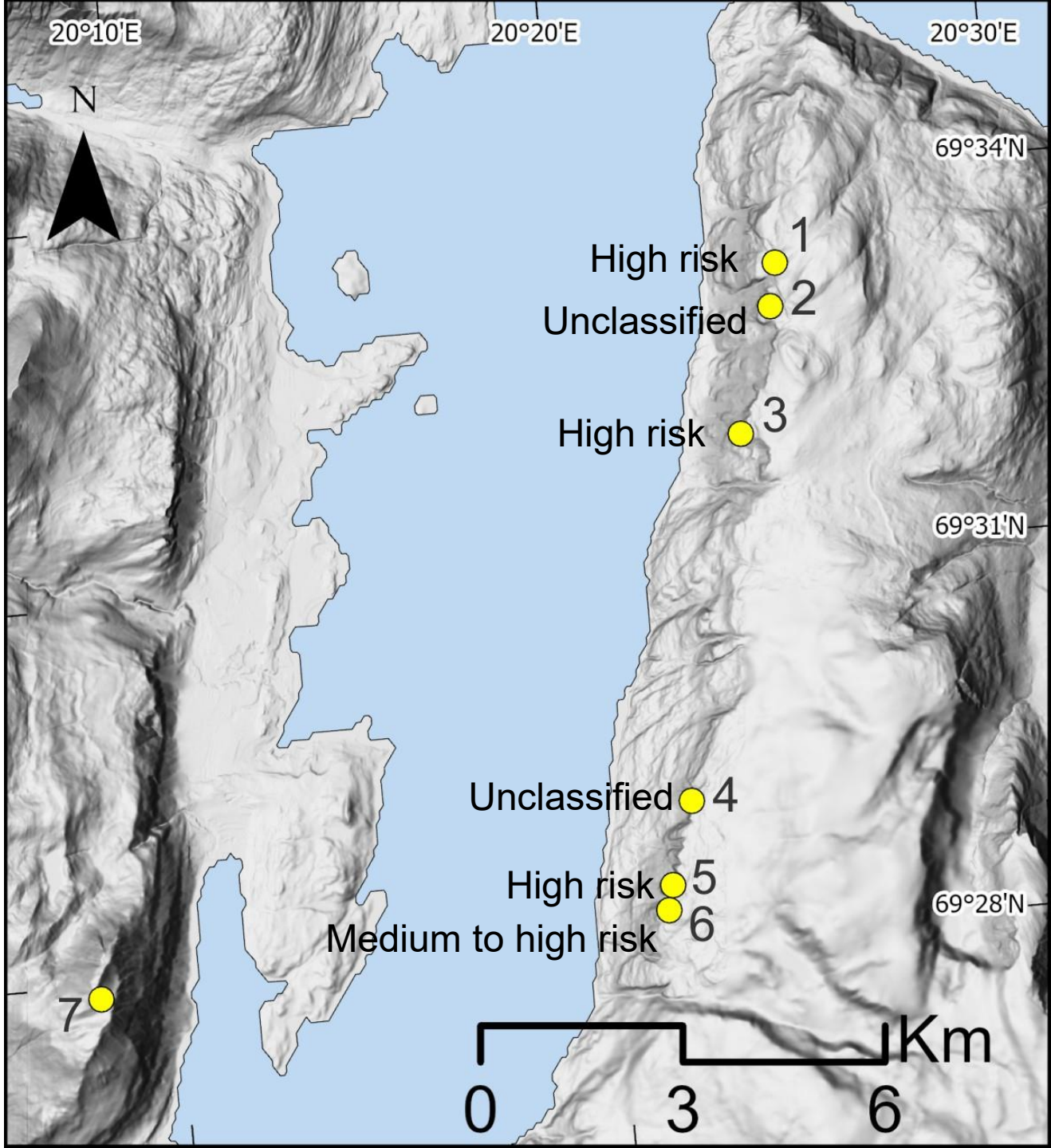
Joint controlled

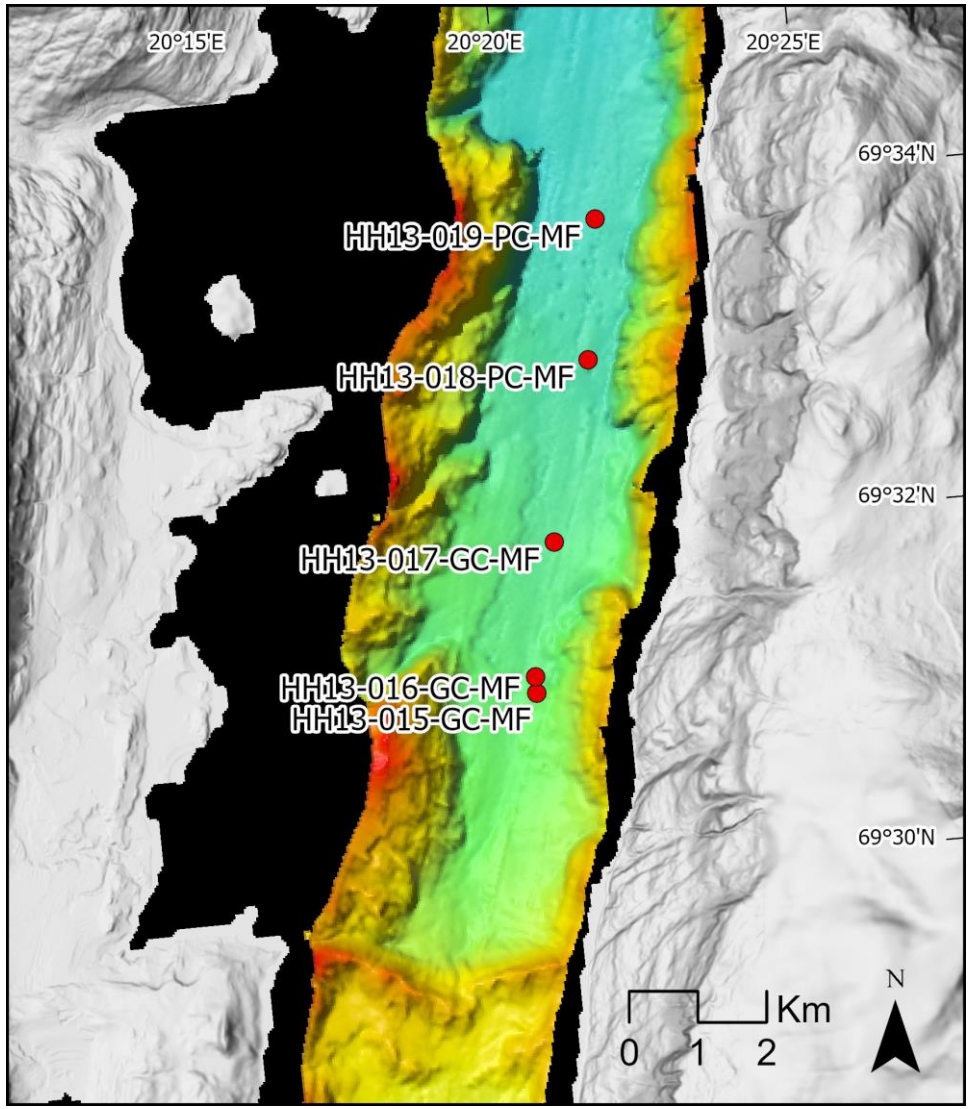
Fault controlled



Vick et al 2020


Risikomatrise Jettan
12
Svært høy
9,6
Høy
7,2
Middels
4,8
Lav
2,4
Svært lav
0
Fareklasse (farepoeng)
1/100
1/1000
1/5000
Nominell årlig sannsynlighet
0,1
1
10
100
1000
10000
Svært lav
Lav
Middels
Høy
Svært høy
Konsekvensklasse
(potensielt tap av menneskeliv)


20°10'E
20°20'E
20°30'E
N
69°34'N
69°31'N
69°28'N
High risk
1
Unclassified
2
High risk
3
Unclassified
4
High risk
5
6
Medium to high risk
7
Km
0
3
6


20°15'E
20°20'E
20°25'E
69°34'N
69°32'N
69°30'N
HH13-019-PC-MF
HH13-018-PC-MF
HH13-017-GC-MF
HH13-016-GC-MF
HH13-015-GC-MF
0 1 2 Km
N

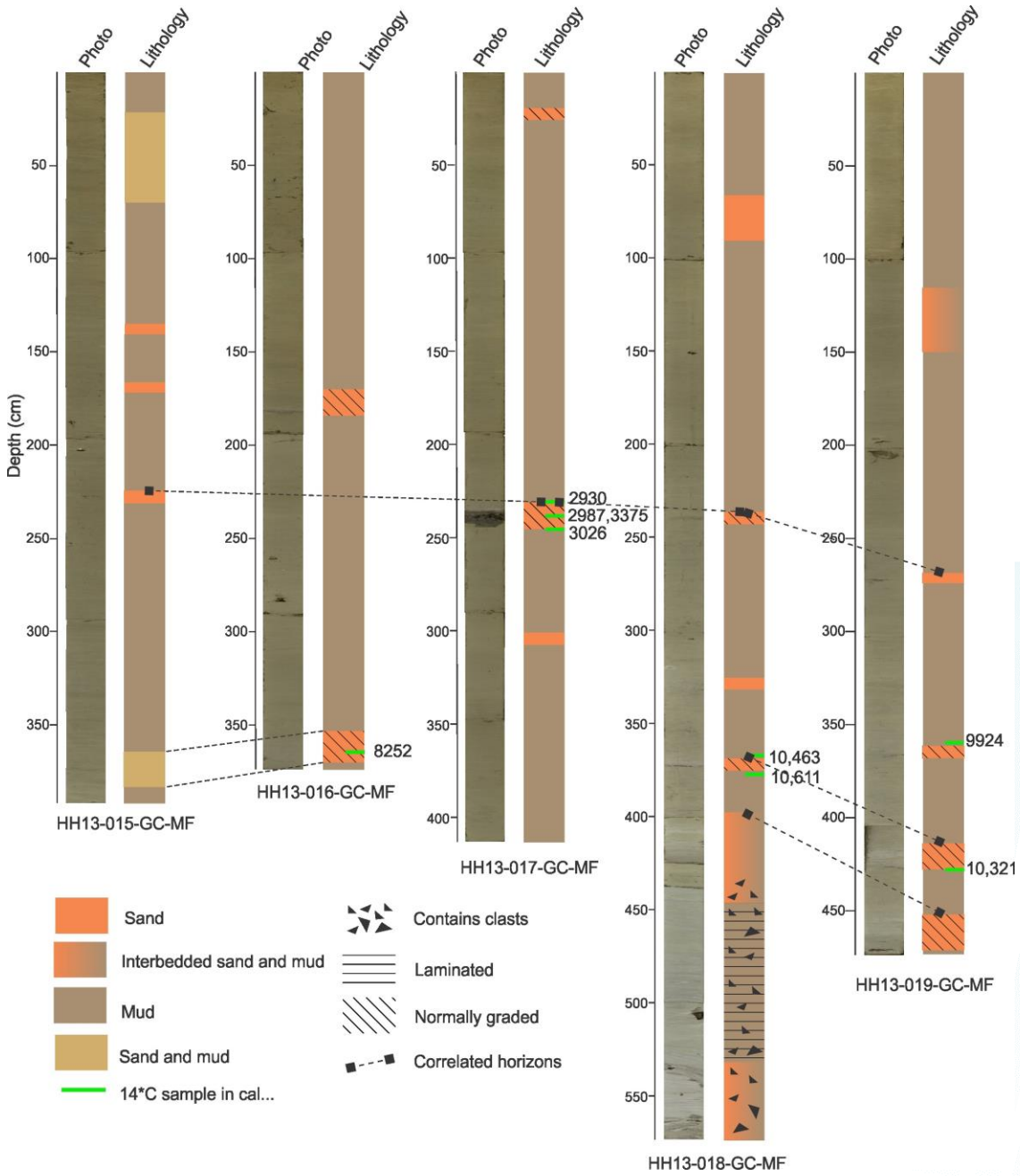
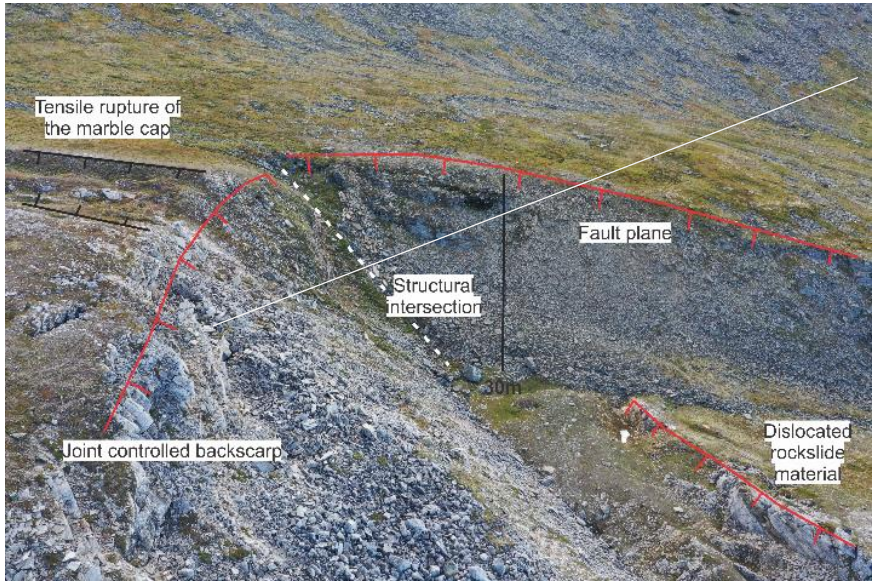
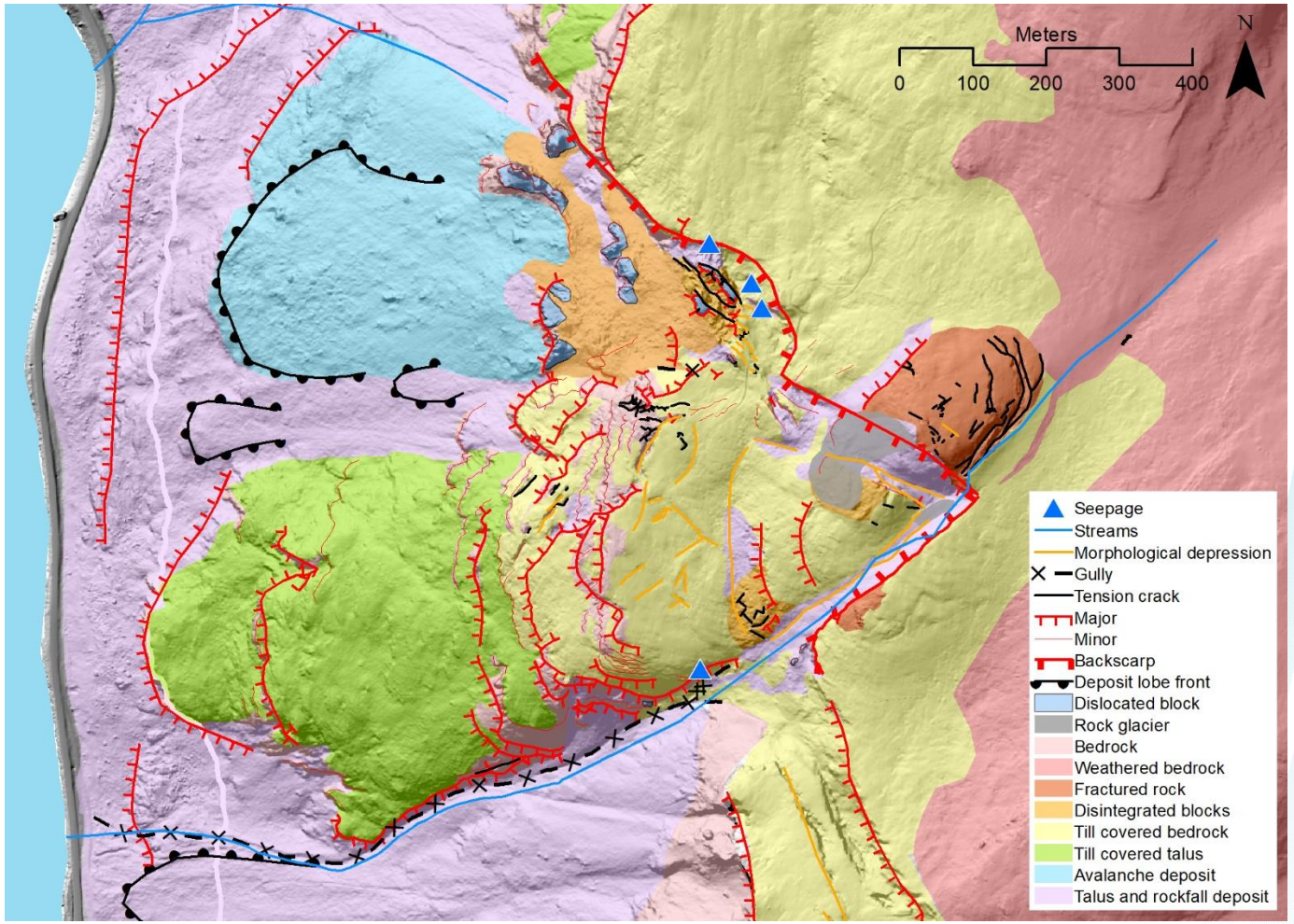


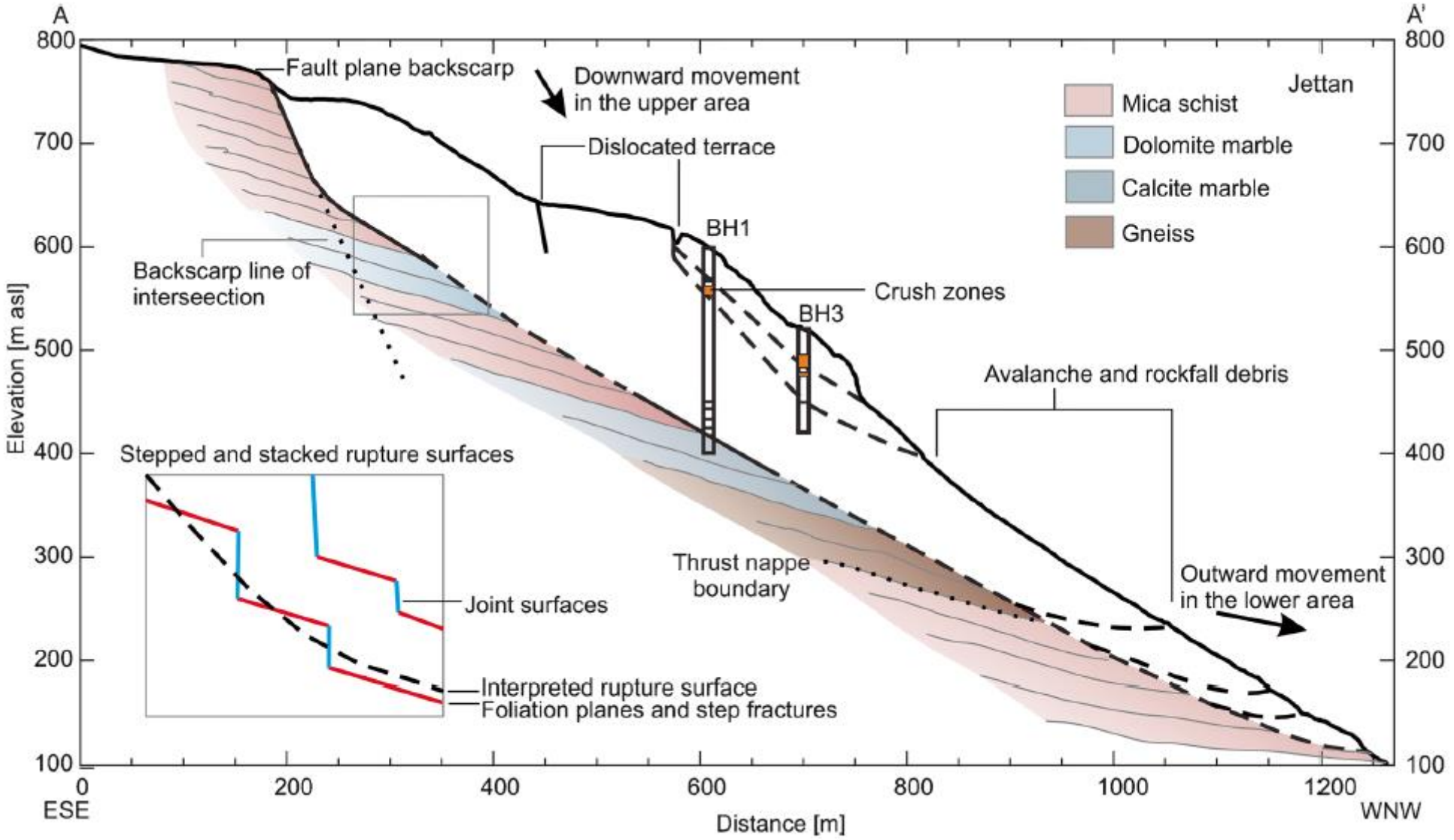
Photo
Lithology
Depth (cm)
50
100
150
200
250
300
350
400
450
500
550
HH13-015-GC-MF
8252
HH13-016-GC-MF
2930
2987,3375
3026
HH13-017-GC-MF
10,463
10,611
HH13-018-GC-MF
9924
10,321
HH13-019-GC-MF
Sand
Interbedded sand and mud
Mud
Sand and mud
14*C sample in cal...
Contains clasts
Laminated
Normally graded
Correlated horizons



Exposure age 6520 ± 335 years BP



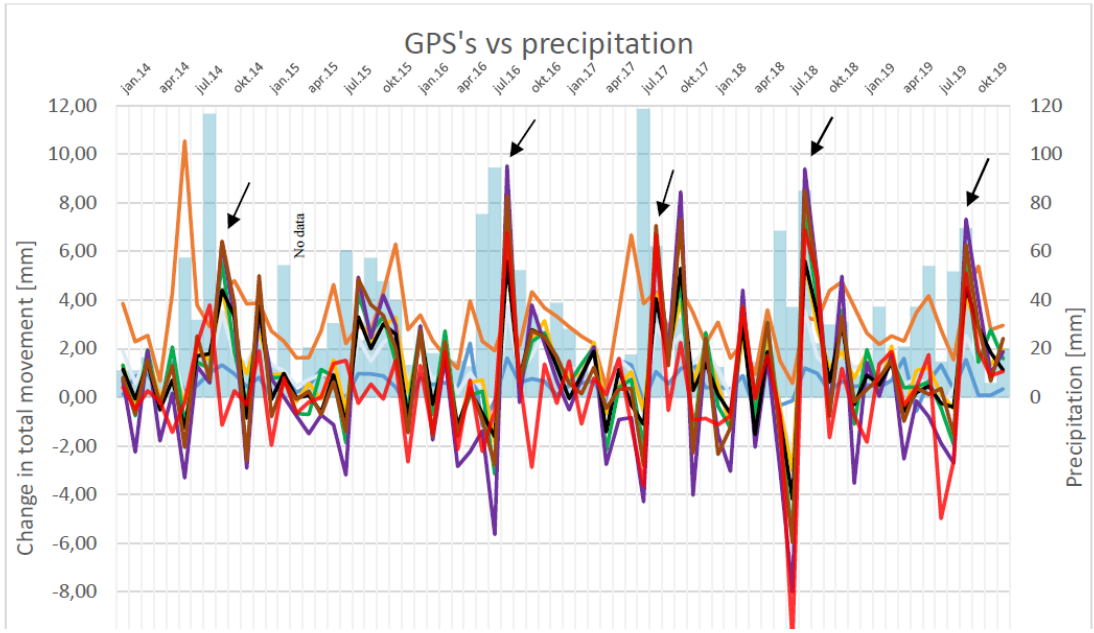
Joints/faults do not daylight

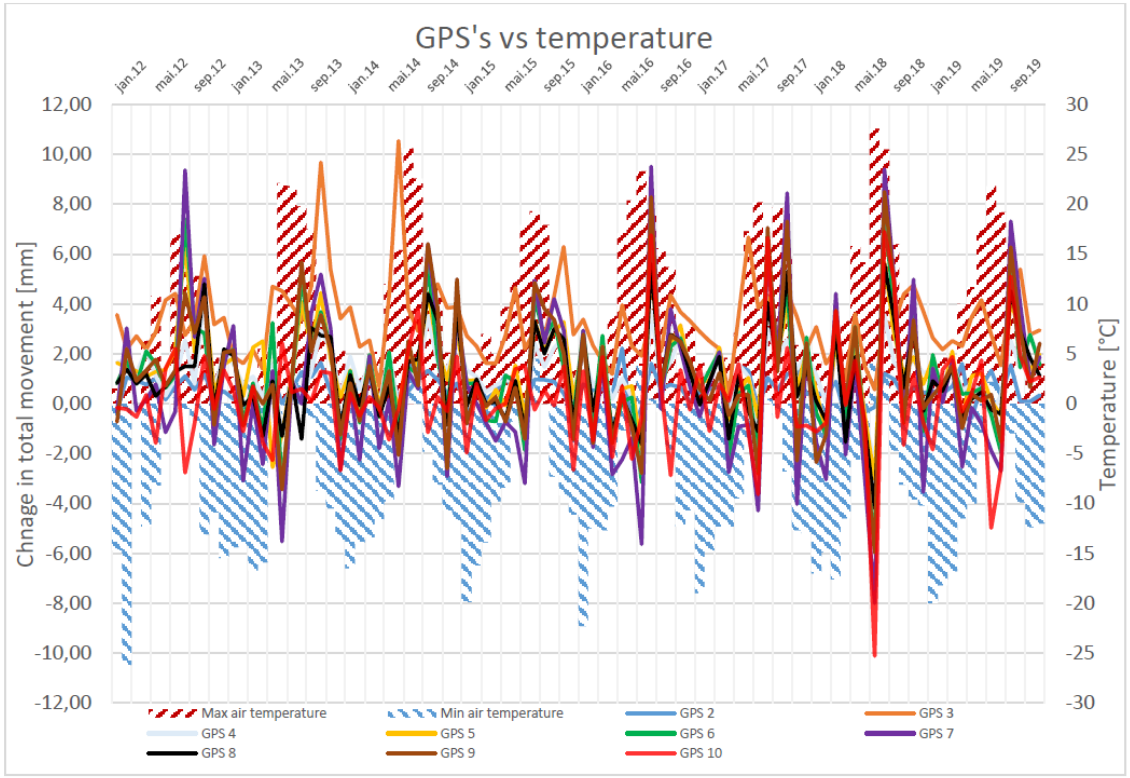

A
A'
800
700
600
500
400
300
200
100
Elevation [m asl]
Fault plane backscarp
Downward movement
in the upper area
Dislocated terrace
BH1
BH3
Crush zones
Backscarp line of
interseection
Stepped and stacked rupture surfaces
Joint surfaces
Interpreted rupture surface
Foliation planes and step fractures
Thrust nappe
boundary
Avalanche and rockfall debris
Outward movement
in the lower area
Jettan
Mica schist
Dolomite marble
Calcite marble
Gneiss
0
200
400
600
800
1000
1200
ESE
WNW
Distance [m]

- Friction angle marble and schist 31-34°
- Foliation dips up to 25°
- Shear strength weak zones 17-18°

- Numerous foliation-parallel weakness zones mapped
- Seen as highly weathered, very weak foliated material or as a heavily deformed ductile shear zone
- Includes pockets of clayey silt soil
- Seepage was observed exiting the weakness zones, increasing weathering along these weaker zones.
- History of the rock- thrust faults

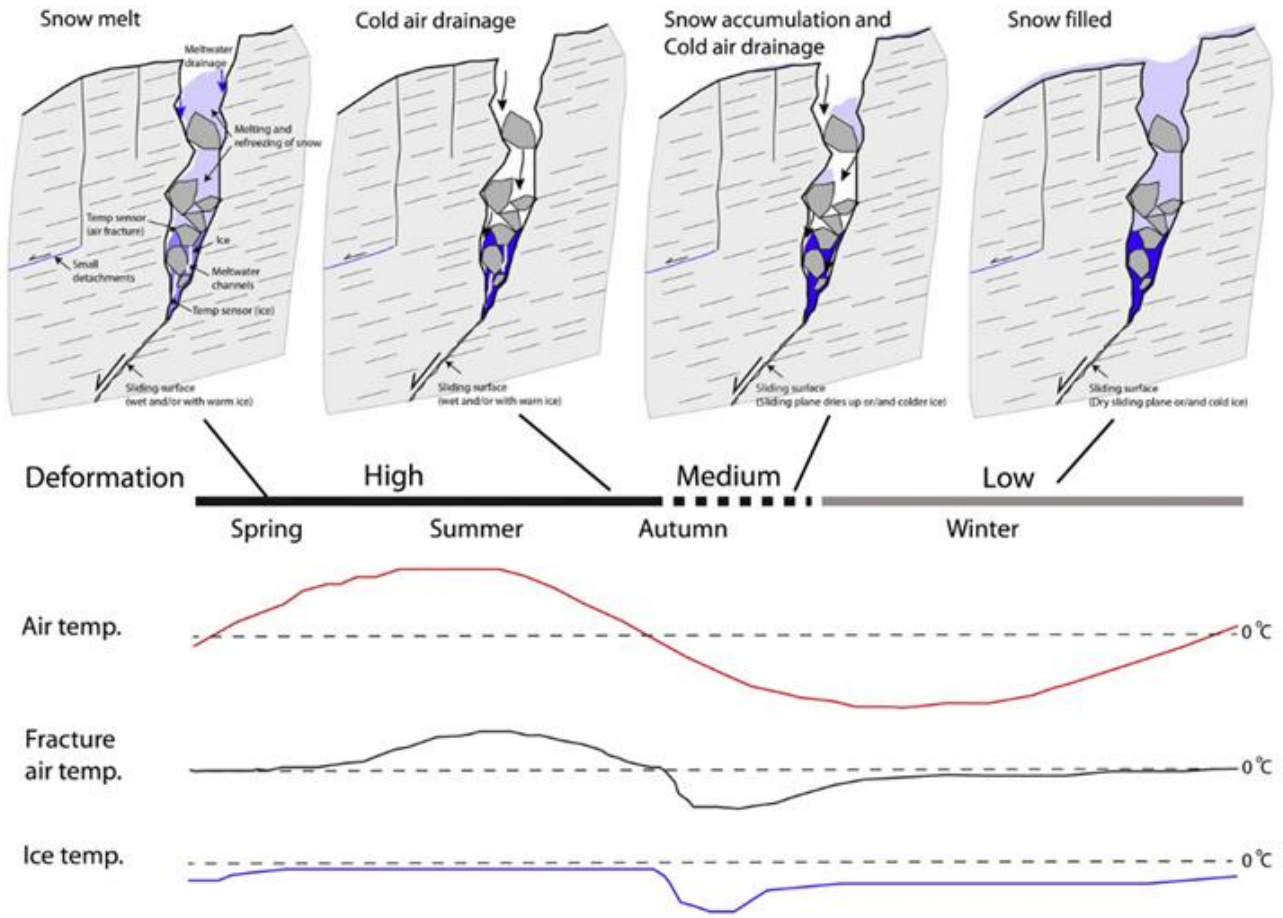
- Surface movement seen weeks to a month after rainfall
- Highest temperatures precede largest surface moments
- Larger changes begin in the spring after temperatures rise above 0, additional negative trend indicating melt of fracture ice
- Extensometers show (in general) negative changes in midwinter, and positive changes in late spring/early summer
- Lasers, crack meters and other instruments consistent with this



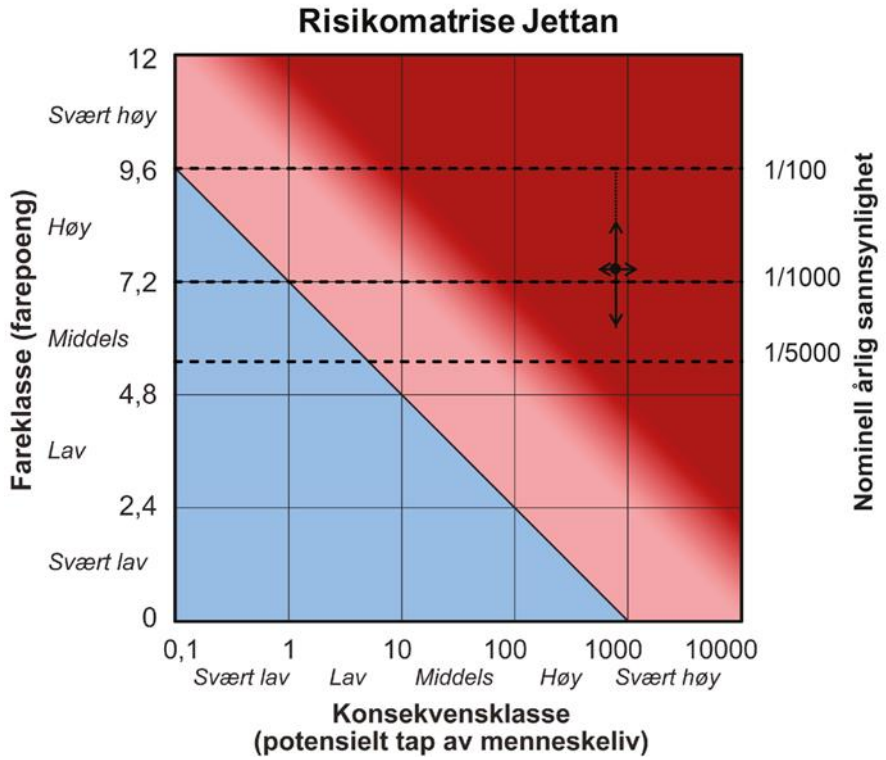


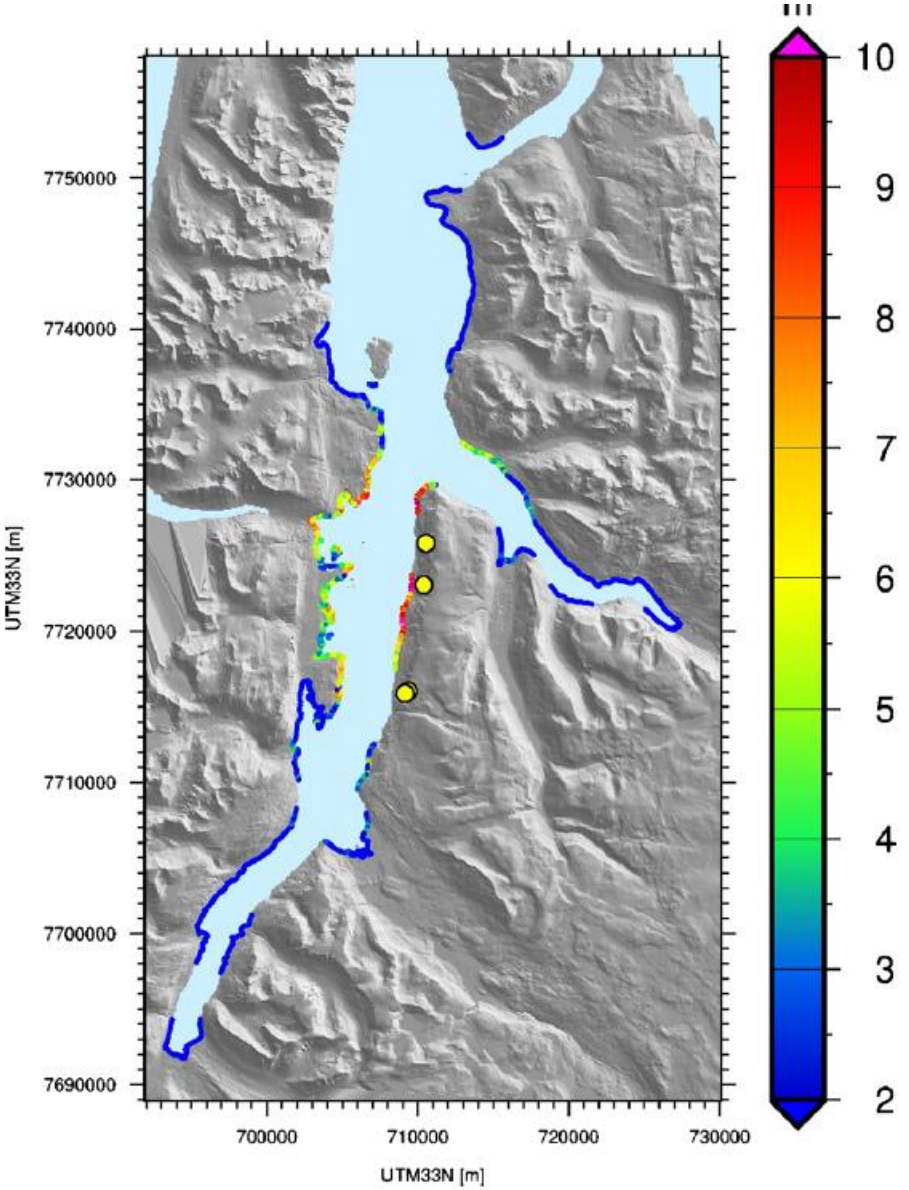
Permafrost and seasonal displacements

- Topography, accumulation of snow and joint patterns leads to localized permafrost
- Ice temperature fluctuates
- Poor pressure changes as driver of deformation



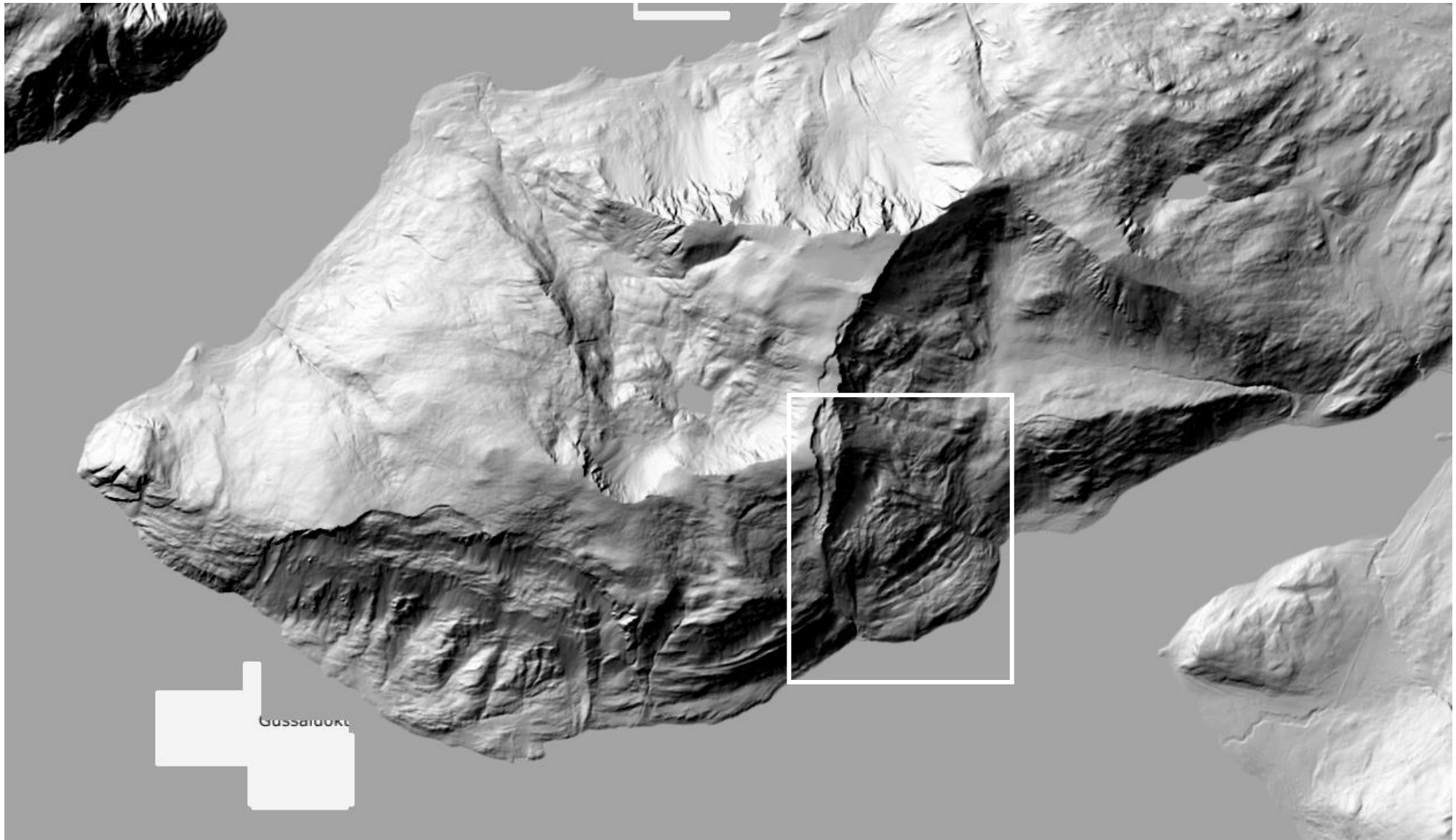
Blikra and Christiansen 2014

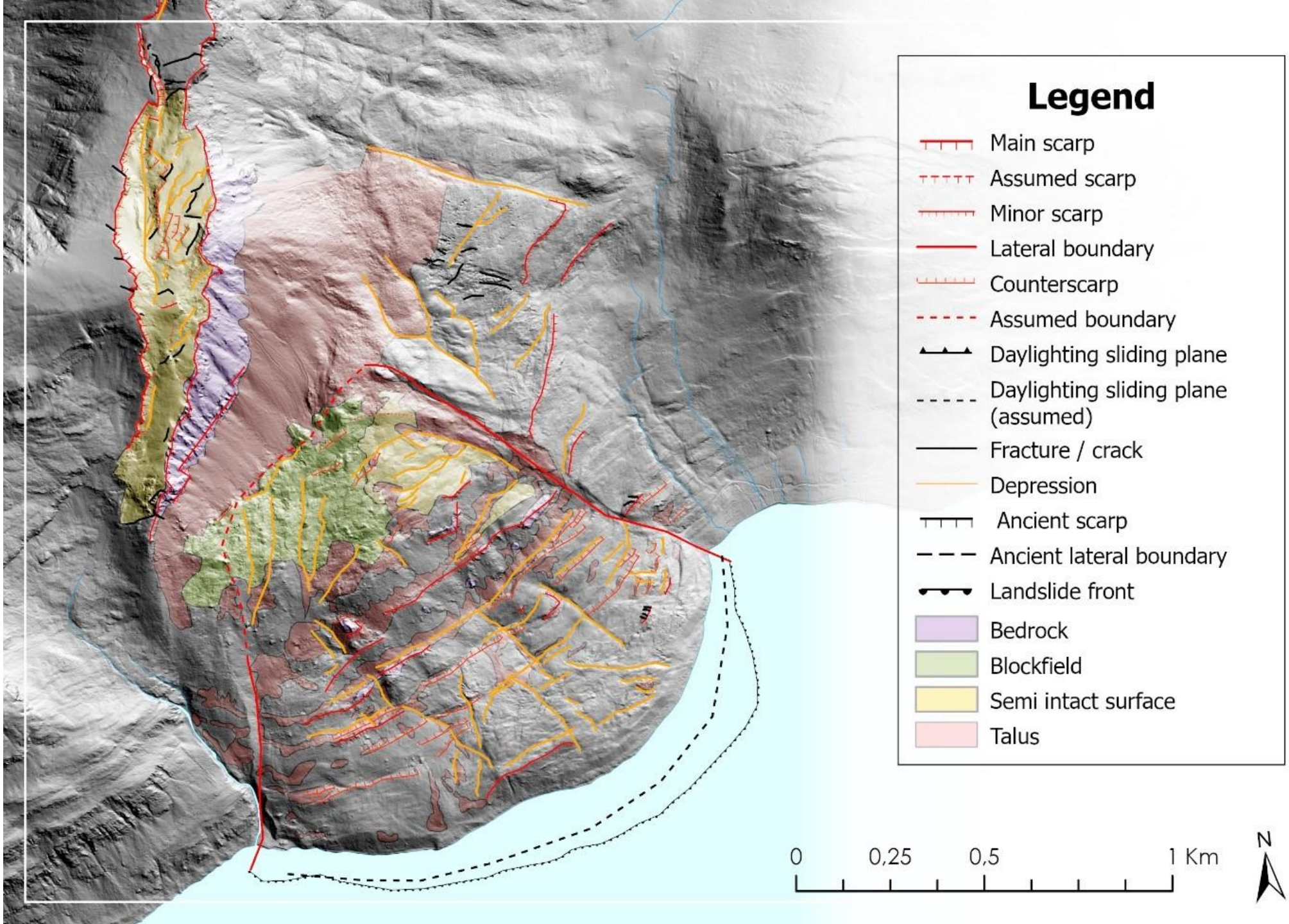


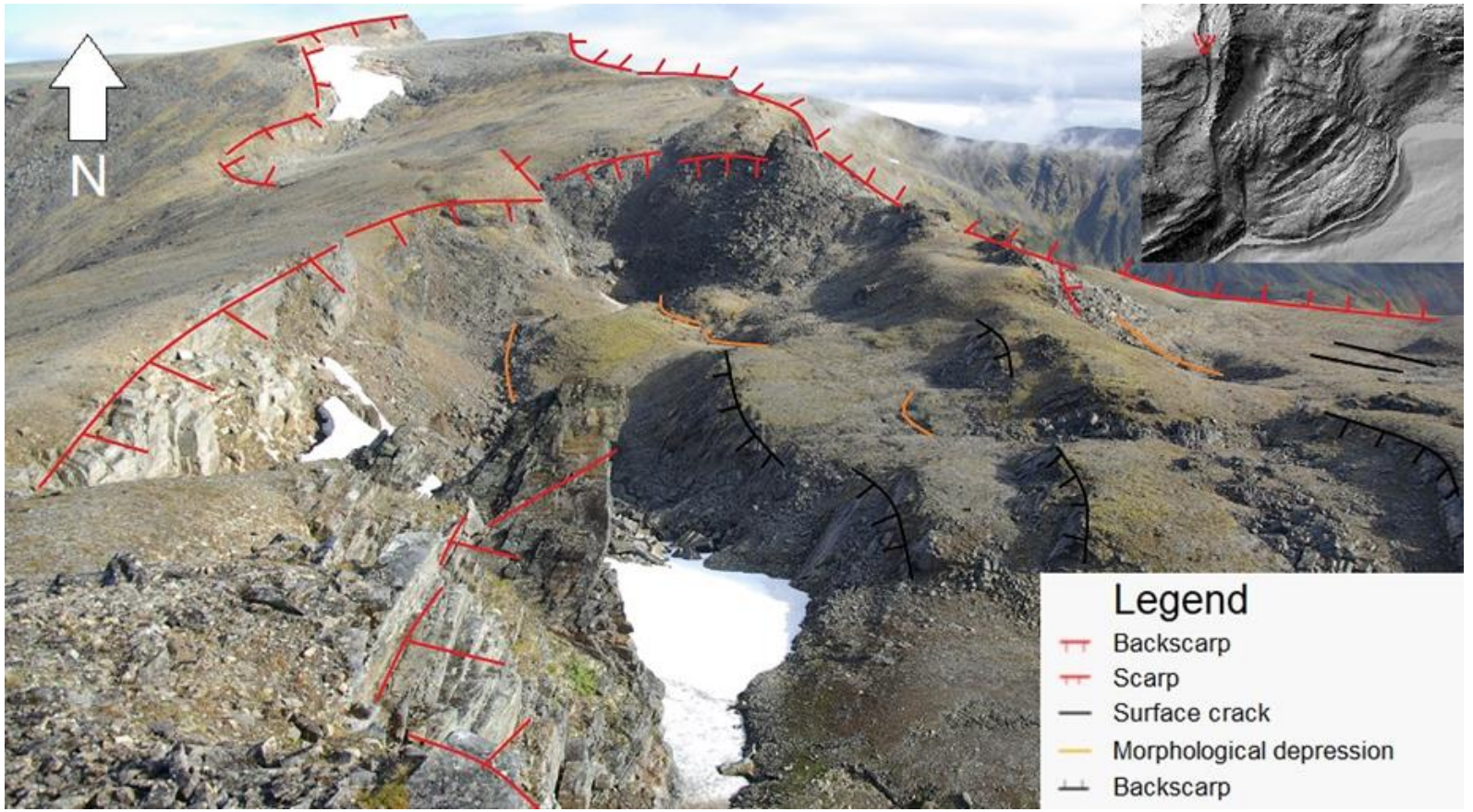


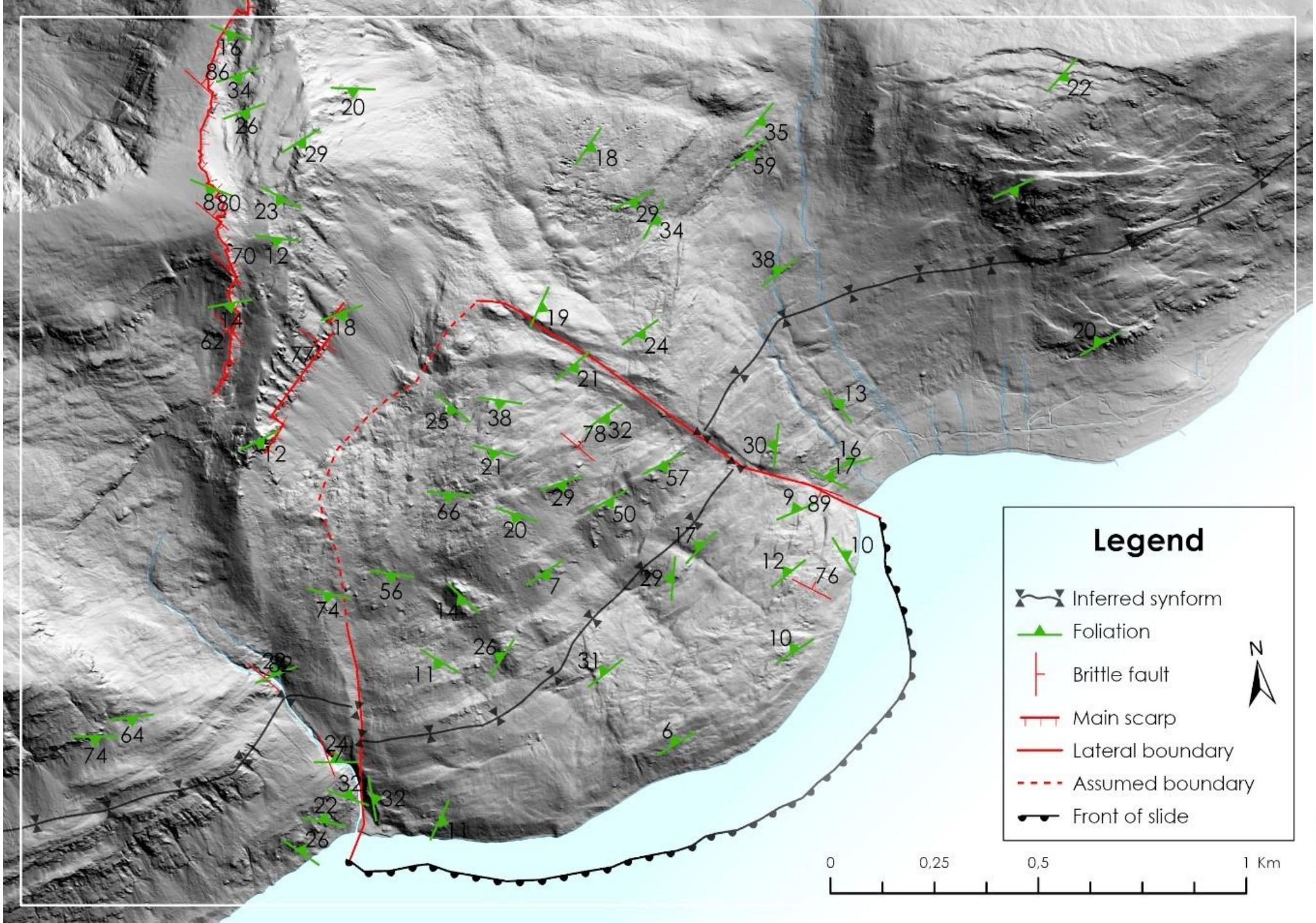
Løvholt et al 2020

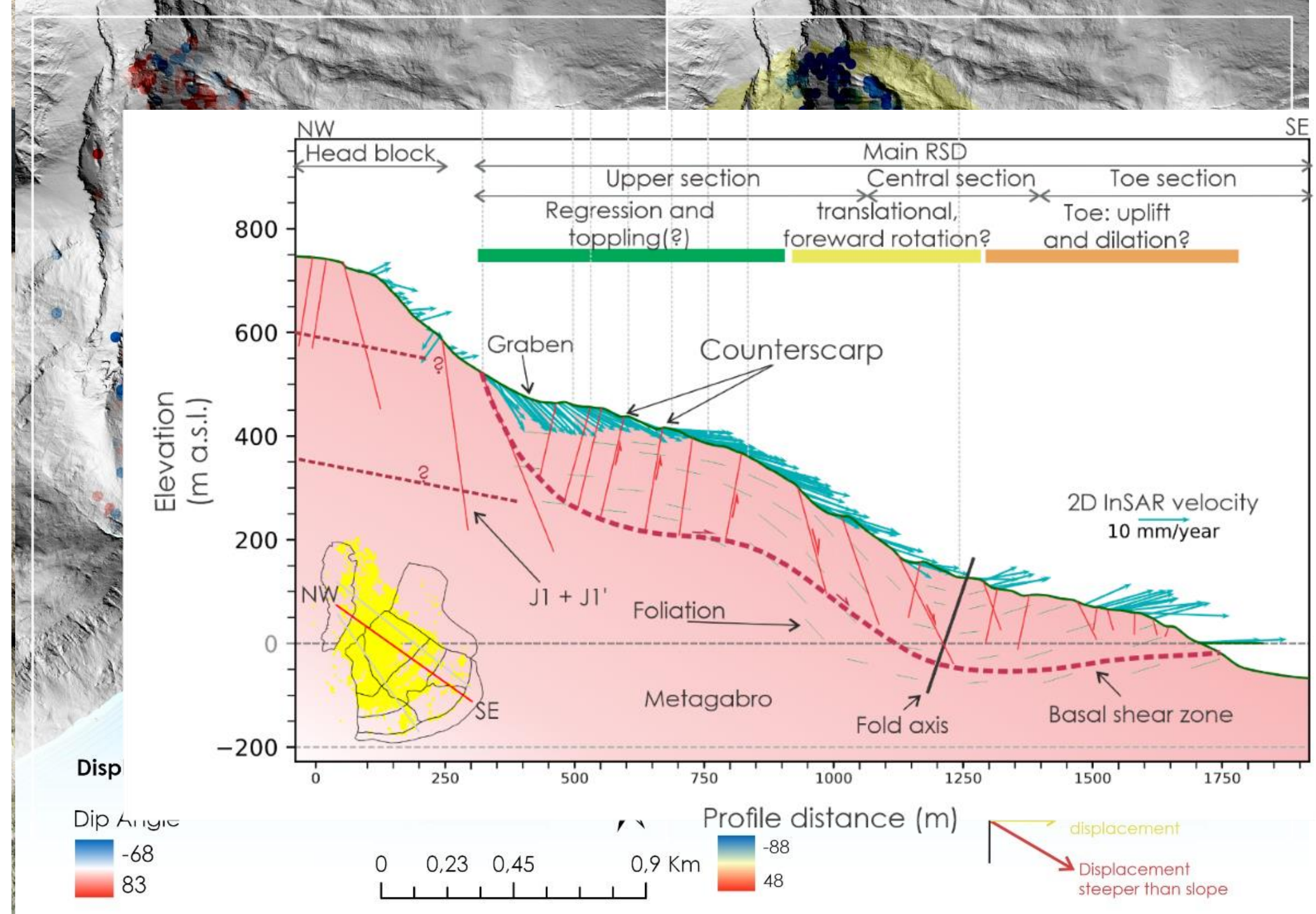
Dusnjarga

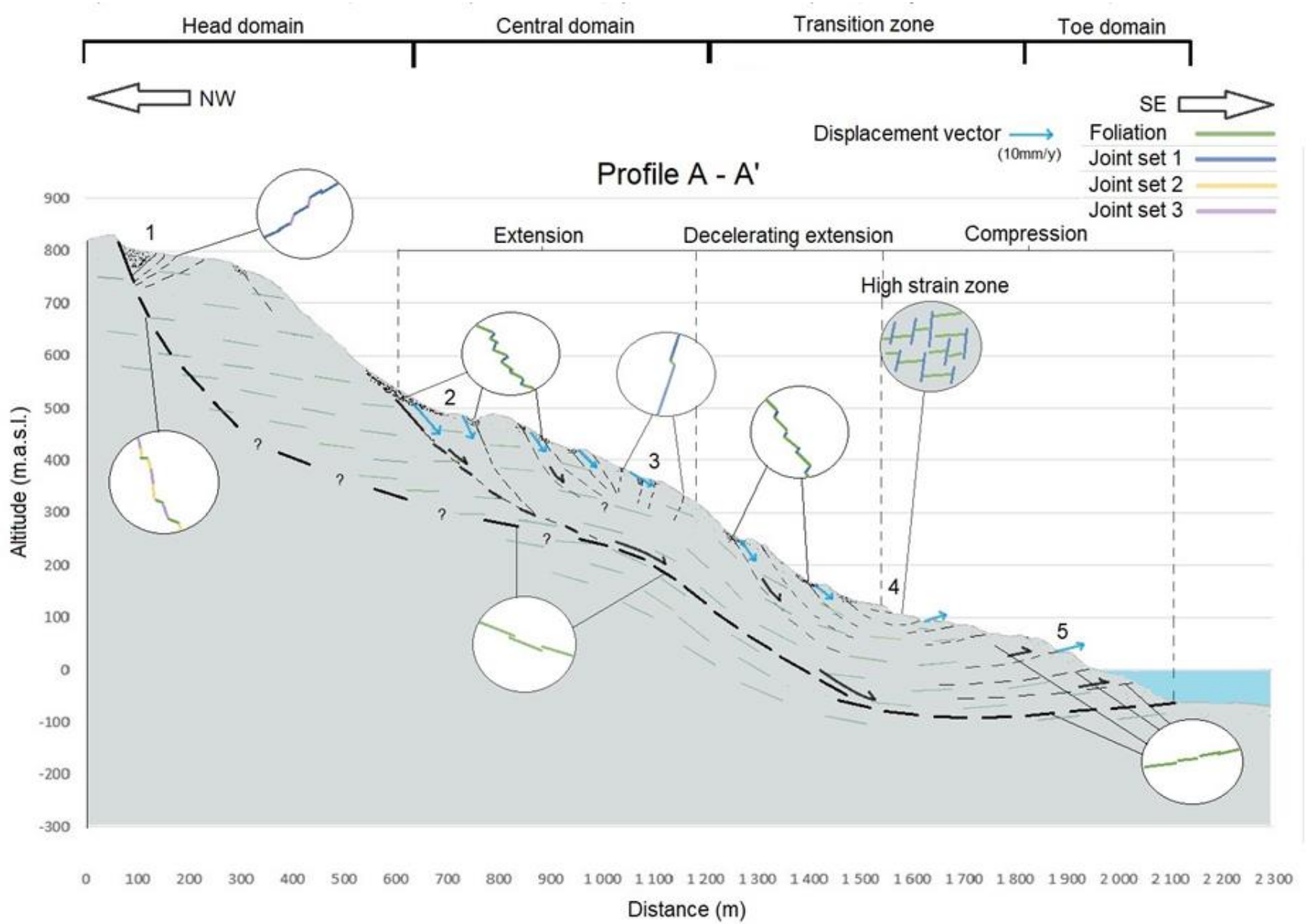


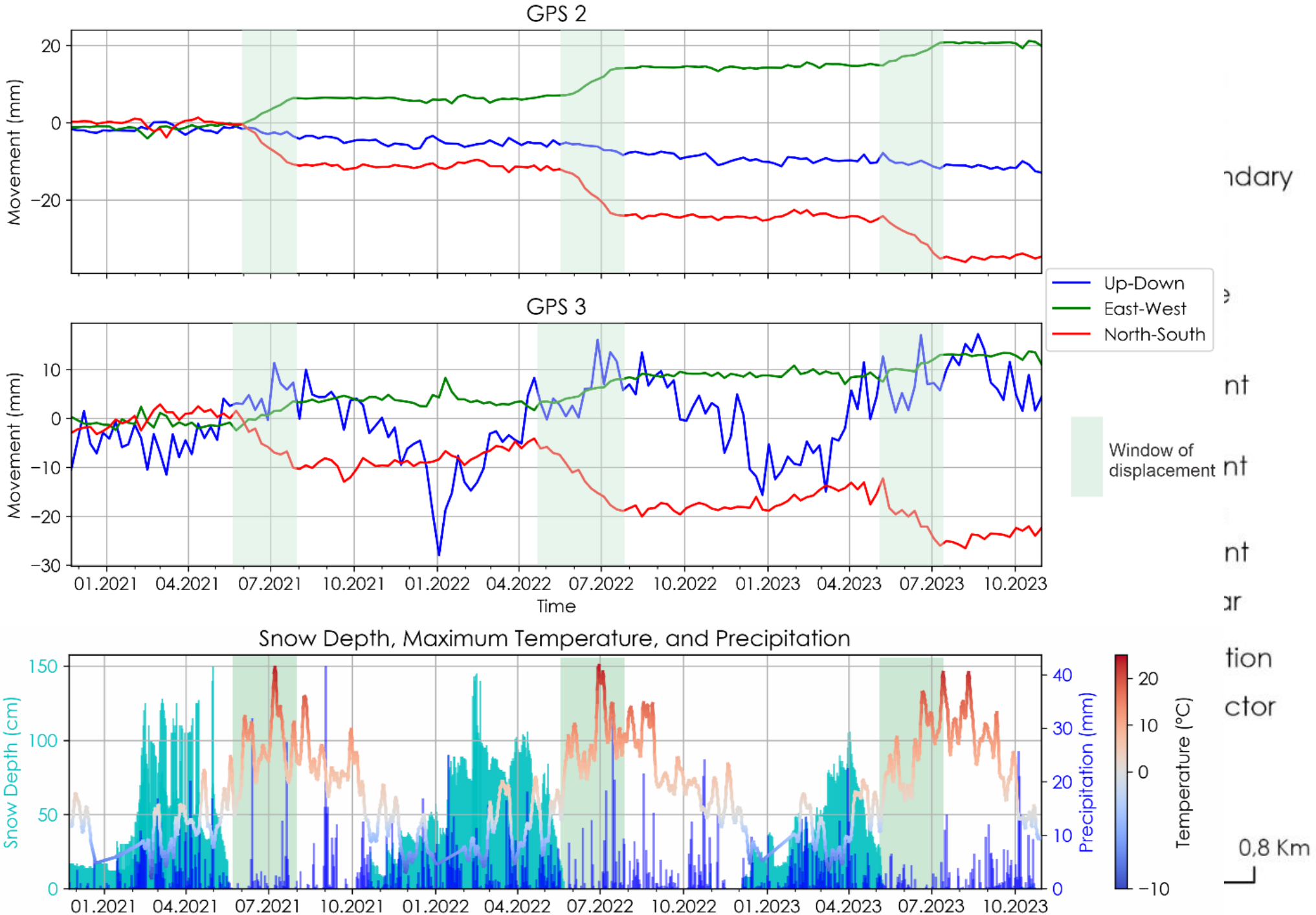

Legend
Main scarp
Assumed scarp
Minor scarp
Lateral boundary
Counterscarp
Assumed boundary
Daylighting sliding plane
Daylighting sliding plane (assumed)
Fracture / crack
Depression
Ancient scarp
Ancient lateral boundary
Landslide front
Bedrock
Blockfield
Semi intact surface
Talus
0
0,25
0,5
1 Km
N


N
Legend
Backscarp
Scarp
Surface crack
Morphological depression
Backscarp


Legend
Inferred synform
Foliation
Brittle fault
Main scarp
Lateral boundary
Assumed boundary
Front of slide
N
0
0,25
0,5
1 Km


NW
SE
Head block
Main RSD
Upper section
Central section
Toe section
Regression and toppling(?)
translational, foreward rotation?
Toe: uplift and dilation?
Graben
Counterscarp
Elevation (m a.s.l.)
800
600
400
200
0
−200
2D InSAR velocity
10 mm/year
NW
SE
J1 + J1'
Foliation
Metagabro
Fold axis
Basal shear zone
0
250
500
750
1000
1250
1500
1750
Profile distance (m)
Dip Angle
-68
83
-88
48
0
0,23
0,45
0,9 Km
displacement
Displacement steeper than slope


Head domain
Central domain
Transition zone
Toe domain
NW
SE
Displacement vector
(10mm/y)
Foliation
Joint set 1
Joint set 2
Joint set 3
Profile A - A'
Extension
Decelerating extension
Compression
High strain zone
1
2
3
4
5
Altitude (m.a.s.l.)
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
0
100
200
300
400
500
600
700
800
900
1 000
1 100
1 200
1 300
1 400
1 500
1 600
1 700
1 800
1 900
2 000
2 100
2 200
2 300
Distance (m)


GPS 2
Movement (mm)
20
0
−20
GPS 3
Movement (mm)
10
0
−10
−20
−30
01.2021
04.2021
07.2021
10.2021
01.2022
04.2022
07.2022
10.2022
01.2023
04.2023
07.2023
10.2023
Time
Up-Down
East-West
North-South
Window of displacement
Snow Depth, Maximum Temperature, and Precipitation
Snow Depth (cm)
150
100
50
0
Precipitation (mm)
40
30
20
10
0
Temperature (°C)
20
10
0
−10
0,8 Km